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(54) **FUEL ASSEMBLY FOR A LIGHT-WATER NUCLEAR REACTOR AND LIGHT-WATER NUCLEAR REACTOR**

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ASSEMBLAGE COMBUSTIBLE DE RÉACTEUR À EAU ORDINAIRE ET RÉACTEUR À EAU ORDINAIRE

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Description

Pertinent Art

[0001] The invention in general falls into the category of the structural elements of light-water nuclear reactors in which thorium is used as the fuel, and in particular, into the category of the structural elements of the jacketless fuel assemblies in the shape of a square from which the cores of water-cooled, water-moderated power reactors are formed, which are known as reactors of the PWR type (for example, the AP-1000, the EPR, etc.).

Prior Knowledge

[0002] Nuclear power is still an essential energy resource around the world today. Many countries that do not have adequate fossil fuel resources primarily rely on nuclear power to generate electricity. In many other countries, nuclear power is used as a competing source for the generation of electricity, which also increases the diversity of the types of energy used. In addition, nuclear power also makes a very significant contribution to the achievement of goals such as the management of the environmental pollution associated with fossil fuel (for example, acid rain and global warming) and the preservation of fossil fuel for future generations.

[0003] Despite the fact that safety is unequivocally the principal issue surrounding the design and operation of nuclear reactors, another key issue includes of the danger of the proliferation of materials that can be used in nuclear weapons. This is especially true for countries with unstable governments, the possession of nuclear weapons by which might pose a considerable threat to the world security. For this reason, nuclear power must be generated and used in such a manner that it does not lead to the proliferation of nuclear weapons and the resulting risk of their use.

[0004] All the nuclear reactors in existence at this time produce a large quantity of a material that is customary to call it reactor-grade plutonium. For example, a conventional 1,000-megawatt (MW) reactor generates in the magnitude of 200-300 kilograms (kg) of reactor-grade plutonium a year that might be suitable for making nuclear weapons. Thus, the fuel discharged from the cores of conventional reactors is an intensely multiplying material and requires precautionary measures in order to ensure that the discharged fuel does not fall into the hands of individuals who do not have the right to possess it. A similar security problem also exists relative to the enormous stockpiles of weapons-grade plutonium that are created in the United States of America (USA) and the countries of the former Union of Soviet Socialist Republics (USSR) when nuclear weapons were dismantled.

[0005] Another problem associated with the operation of conventional nuclear reactors stems from the ongoing need for long-lived radioactive waste disposal, as well as the rapid depletion of world resources of natural uranium raw materials.

[0006] In order to resolve these problems, attempts have recently been made to create nuclear reactors that operate on relatively small quantities of nonproliferative enriched uranium (enriched uranium has a U-235 content of 20% or less) and that do not produce significant quantities of multiplying materials such as plutonium. Examples of such reactors were disclosed in international applications WO 85/01826 and WO 93/16477, wherein reactors with a seed-and-breeding core containing a seed region and a breeding region are presented that derive a considerable percentage of their power from the breeding regions, with thorium serving as the fuel. The breeding regions encircle a seed region, within which fuel rods made from nonproliferative enriched uranium are located. The uranium in the seed region fuel rods emits neutrons that are captured by the thorium in the breeding regions, by virtue of which U-233, capable of nuclear fission, is created, which burns *in situ* and releases heat for the reactor power plant.

[0007] The use of thorium as a nuclear reactor fuel is appealing, since thorium reserves around the world significantly exceed uranium reserves. Furthermore, both reactors mentioned above are nonproliferative in the sense that neither the initially charged fuel nor the fuel discharged at the end of each fuel cycle is suitable for making nuclear weapons. This is achieved by virtue of the fact that only nonproliferative enriched uranium is used as the seed region fuel, during which moderator/fuel volume ratios are selected that result in the minimal formation of plutonium. And a small quantity of nonproliferative enriched uranium is added to the breeding region, within which the U-238 component is homogeneously mixed with the left over U-233 at the end of the breeding cycle and "denatures" the U-233 (alters its natural properties), as a result of which it becomes unsuitable for making nuclear weapons.

[0008] Unfortunately, neither of the reactor designs cited above is truly "nonproliferative." In particular, it was discovered that both these designs result in a level of proliferative plutonium formation in the seed region that exceeds the minimum possible level. The use of a round seed region with an internal or central breeding region and an external encircling breeding region cannot ensure the operation of a reactor as a "nonproliferative" reactor, since the thin round seed region has a correspondingly small "optical thickness", resulting in the fact that the seed region (of neutrons) spectrum will be dominant over the considerably harder spectrum of the internal and external breeding regions. This leads to the origination of a larger share of epithermal neutrons in the seed region, as well as to the production of multiplying plutonium, in a quantity larger than the minimum amount.

[0009] In addition, neither of these foregoing reactor designs has been optimized from the reference point of operating parameters. For example, the moderator/fuel volume ratios in the seed region and the breeding regions are especially critical for the production of a minimum quantity of plutonium in the seed region, in order to ensure an adequate amount of heat to be released from the fuel rods in the seed region and for the optimum conversion of thorium into U-233 in the breeding region. Research has shown that the preferred moderator/fuel ratio values, specified in these international applications, are too high in the seed regions and too low in the breeding regions.

[0010] The foregoing core designs were also not especially efficient when nonproliferative enriched uranium was used in the seed region fuel elements. As a result the fuel rods discharged at the end of each seed region fuel cycle, consequently contained so much leftover uranium that it was necessary to process them for reuse in another reactor core.

[0011] The reactor disclosed in application WO 93/16477 also requires a complicated reactor mechanical control circuit that makes it unsuitable for re-equipment of a conventional reactor core. Likewise, the core of the reactor disclosed in application WO 85/01826 cannot be easily transferred to a conventional core, since its design parameters are not compatible with those of a conventional core.

[0012] Finally, both foregoing reactor designs were specially conceived for burning nonproliferative enriched uranium with thorium and are not suitable for the use of a large quantity of plutonium. Accordingly, neither of these designs ensures the resolution of the problem of the stored accumulated plutonium.

[0013] A reactor is known from patent RU 2176826 with a core, includeing of a number of seed-and-blanket regions, each of which contains a central seed region. Every seed region includes fuel elements of the seed region, made from a material capable of nuclear fission that contains uranium-235 and uranium-238, a circular breeding region that surrounds the seed region. The reactor also includes of the breeding fuel elements of the breeding region, which primarily contain thorium and enriched uranium in a volume of 10% or less, a feed region moderator, where the moderator/fuel volume ratio falls within a value range of 2.5 to 5.0, and a breeding region moderator, where the moderator/fuel ratio falls within a value range of 1.5-2.0. Herewith, each of the seed region fuel elements includes of a uranium-zirconium (U-Zr) alloy and the seed region comprises 25-40% of the total volume of each seed-and-blanket region.

[0014] The known reactor ensures the optimum operation from the standpoint of economy and is not "proliferative". This reactor can be used to consume large quantities of plutonium and thorium without simultaneously producing waste products that constitute proliferative materials. Herewith, the subject reactor generates considerably smaller quantities of highly radioactive waste products, as a result of which the need for long-term waste storage locations is diminished.

[0015] However, the seed-and-blanket regions employed in this reactor are not suitable for use in existing light-water reactors of the PWR type cited above (for example, the AP-1000, the EPR, etc.).

[0016] A light-water reactor fuel assembly is known from the description for patent RU 2222837, which is similar to the previously described reactor, that has, in particular, a square-shaped cross-section that makes it possible to install this fuel assembly, made up of seed-and-blanket regions, in a conventional light-water reactor.

[0017] However, other than indicating the shape of the assembly's cross-section, the description for the patent cited above does not contain information on the assembly structural variations that would facilitate its installation in an existing light-water reactor of the PWR type (for example, the AP-1000, the EPR, etc.) without making changes of any kind in the reactor's design.

[0018] A light-water reactor fuel assembly is known from patent RU 2294570 that contains a fuel element bundle, guide tubes housed in spacer grids, a lower nozzle, and a upper nozzle, where the spacer grids are also interconnected to the lower nozzle by components positioned along the length of the fuel assembly, while the upper nozzle includes of upper and lower connected plates, a shell ring that is positioned between these plates, and a spring assembly; here, the upper nozzle shell ring is equipped with outer ribs, the protruding sections of which are interconnected by a rim and the lower section of which are interconnected by perforated plates.

[0019] The known fuel assembly falls into the category of jacketless fuel assembly designs, from which the cores of water-cooled, water-moderated power reactors of the VVER- 1000 type are formed, and has enhanced performance properties due to the increased rigidity and decreased length of the upper nozzle, as well as an enlarged free space between the fuel element bundle and the upper nozzle, accompanied by a simultaneous increase in fuel element length. This makes it possible to increase fuel assembly's charging with a fuel that has a high burnup fraction and thus to increase reactor core power, as well as fuel assembly operating time.

[0020] However, all the fuel elements in this assembly are made from the fissile material traditionally used in light-water reactors; consequently, the shortcoming previously described is inherent in a reactor with assemblies of this type - the production of a large quantity of reactor-grade plutonium. Moreover, the subject assembly has been adapted for reactors of the VVER-1000 type; i.e., it has a hexagon-shaped cross-section, which does not match the shape of the fuel assemblies used in reactors of the PWR type (for example, the AP-1000, the EPR, etc.).

[0021] Other fuel assemblies are known e.g. from US2002/0080908, US3252867, or US5737375.

[0022] The objective of the invention includes of creating a fuel assembly that generates a considerable portion of its power in a breeding region that contains thorium as the fuel on the one hand and does not produce wastes that constitute proliferative materials during its use. On the other hand, it can be placed into an existing light-water reactor of the PWR type (for example, the AP-1000, the EPR, etc.) without the need for its substantial modification.

Disclosure of the Invention

[0023] This objective is achieved by fuel assemblies as specified in the claims.

Brief Description of the Drawings

[0024] The particularities and advantages of the invention at hand will be obvious from the following detailed description of its preferred embodiments taking the attached drawings into account, in which:

Fig. 1 - offers a general view of a fuel assembly that conforms to the first embodiment of the invention;
Fig. 2 - a cross-sectional layout view of a fuel assembly that conforms to the first embodiment of the invention;
Fig. 3 - a general view of a fuel assembly that conforms to the second embodiment of the invention;
Fig. 4 - a cross-sectional layout view of a fuel assembly that conforms to the second embodiment of the invention;
Fig. 5 - a layout view of the location of the fuel elements in the peripheral region of the seed region that conforms to the second embodiment of the invention;
Fig. 6 - a layout view in the perspective of a seed region fuel element;
Fig. 7 - a cross-sectional layout view of a seed region fuel element;
Fig. 8 - a layout view of one version of the seed and blanket region lower nozzle connection;
Fig. 9 - a layout view of the blanket region fuel element location in a spacer grid;
Fig. 10 - a cross-sectional layout view of a reactor core that contains fuel assemblies executed according to the invention.

Embodiments of the Invention

[0025] A fuel assembly designated as collective item 1 according to the first embodiment of the invention is shown in Fig. 1. Fuel assembly 1 contains a seed region 2, a blanket region 3, a upper nozzle 4, a seed region lower nozzle 5, and a blanket region lower nozzle 6. As shown in Fig. 2, seed region 2 contains fuel element bundle 7, while blanket region 3 contains fuel element bundle 8. Each of the fuel elements in bundle 7 has a four-lobed profile that forms spiral spacer ribs, 9 (Fig. 6), along the length of a fuel element and contains a kernel, 10 (Fig. 7), that includes enriched uranium or plutonium, as well as a cladding made from a zirconium alloy, 11, that encircles it. A displacer, 12, is located inside kernel 10. All the fuel elements 7 make contact with each adjacent fuel element in bundle 7 at the spiral spacer rib 9 contact points. The spiral spacer rib 9 contact points stand away from one another in the axial direction by a distance equal 25% of the spiral line pitch value.

[0026] Each of the fuel elements 8 has a round shape in the plan view and is made from thorium, with the addition of enriched uranium. The fuel elements module 7 and 8 are arranged in the rows and columns of a square coordinate grid in a cross-section, so that the fuel assembly as a whole has the shape of a square in the plan view. In particular, the fuel elements of module 7 are arranged in the rows of columns of a square coordinate grid, made up of 13 rows and 13 columns, while the fuel elements of blanket region 8 are positioned in the two outermost rows and columns of a square coordinate grid, made up of 19 rows and 19 columns.

[0027] The profiles of each fuel element of bundle 7 have an identical width across corners, amounting, for example, to 12.6 millimeters (mm). The number of fuel elements 7 is 144. The fuel elements 8 have an identical diameter, amounting to, for example, 8.6 millimeters (mm), and are positioned along the sides of the square in two rows and columns of a square coordinate grid. The number of fuel elements 8 is 132.

[0028] A tube 13 is located in the center of seed region 2, which forms a guiding channel for housing the controls therein. Guide tubes 14 are located within the confines of seed region 2 for the insertion of the absorber rods and the safety rods, which are positioned in upper nozzle 4 so as to make axial shifting possible, in addition to which they are linked to lower nozzle 5 of seed region 2 and lower nozzle 6 of blanket region 3 by means of a threaded joint 15 or a collect fixture 16 (Fig. 8).

[0029] Fuel elements' bundle 7 of seed region 2 is encircled by a channel 17, which is secured in lower nozzle 5. The lower end sections of fuel elements' bundle 7 of the seed region 2 are positioned in a supporting frame structure, 18, while their upper end sections are positioned in a guiding grid, 19 (Fig. 1). A fuel element 7 of seed region 2 may be fabricated using the combined molding technique (extrusion through a female die) in the form of a single assembly unit. The spiral line pitch of the spiral spacer ribs, 9, was selected based on the condition of the mutual alignment of axes of adjacent fuel elements 7 at a distance equal to the cross-sectional width across corners of a fuel element and ranges from 5% to 30% of the fuel element's length.

[0030] Blanket region 3 contains a frame structure, formed by four angle elements 20, and four poles 21, that are attached to lower nozzle 6. Spacer grids 22 are secured to a frame structure through the holes in which the fuel elements 8 fuel elements go (Fig. 9). The spacer grids 22 have an opening in their central zone for housing seed region 2 therein.

[0031] A fuel assembly designated as collective item 1', according to the second embodiment of the invention, is shown in Fig. 3. This assembly contains a seed region 2', a blanket region 3', a upper nozzle 4', a seed region lower nozzle 5', and a blanket region lower nozzle 6'. As shown in Fig. 4, seed region 2' contains fuel elements' bundle 7' while blanket region 3' contains fuel elements' bundle 8'.

[0032] Similar to the fuel assembly that conforms to the first embodiment of the invention, each of fuel elements 7' has a four-lobed profile that forms spiral spacer ribs 9 (Fig. 6) along the length of the fuel element and contains a kernel 10 (Fig. 7), which includes enriched uranium or plutonium, as well as a cladding 11, made from a zirconium alloy that surrounds the kernel. Displacer 12 is located inside of kernel 10. Each of fuel elements 8' has a round shape in the plan view and is made from various ceramic formulations of thorium and uranium.

[0033] The fuel elements module 7' and 8' are arranged in the rows and columns of a square coordinate grid in the cross-section, so that the fuel assembly as a whole has the shape of a square in the plan view. In particular, the fuel elements of seed region 7' and blanket region 8' are arranged along 17 rows and 17 columns of a square coordinate grid, at that the fuel elements 7' are arranged in 11 rows and 11 columns in this grid's mid-section.

[0034] The profiles of fuel elements 7', positioned in the outermost rows and columns of a square coordinate grid, have an identical width across corners, amounting, for example, to 10.3 mm. The profiles of remaining fuel elements 7' have an identical and larger width across corners, amounting to, for example, 12.6 mm. The number of fuel elements 7', positioned in the outermost rows and columns of the square coordinate grid is 36 (9 in each outmost row and column of the square coordinate grid), while the number of the remaining fuel elements 7' is 72. The fuel elements 8' have an identical diameter that amounts to, for example, 9.5 mm, and are arranged in three rows and columns of a square coordinate grid. The number of fuel elements 8' is 156.

[0035] Similar to the fuel assembly that conforms to the first embodiment of the invention, a tube 13 is located in the center of seed region 2' that forms a guiding channel for housing the controls therein. Some of the guide tubes 14 are located within the confines of seed region 2' for the insertion of the absorber rods and the safety rods, which are installed in upper nozzle 4 so as to make axial shifting possible and are linked to lower nozzle 5' of seed region 2' by means of a threaded joint 15, or a collet fixture 16 (Fig. 8). The remaining peripheral guide tubes 14' are located within the confines of blanket region 3', is installed in upper nozzle 4 so as to make axial shifting possible, and is linked to lower nozzle 6' of blanket region 3' by means of threaded joint 15 of collet fixture 16 (Fig. 8).

[0036] Similar to the fuel assembly that conforms to the first embodiment of the invention, fuel elements' bundle 7' of seed region 2' is encircled by a channel 17', that is fastened to lower nozzle 5'. The lower end sections of the fuel elements 7' of seed region 2' are positioned in supporting frame structure 18, while their upper end sections are positioned in guiding grid 19 (Fig. 3).

[0037] Similar to the fuel assembly that conforms to the first embodiment of the invention, blanket region 3' contains a frame structure that is formed by peripheral guide tubes 14', for the insertion of the absorber rods and the safety rods installed in upper nozzle 4, so as to make axial shifting possible. Spacer grids 22 are attached to the frame structure, through the openings, through which the fuel elements 8' go (Fig. 9). The spacer grids 22 have an opening in the central zone to accommodate the positioning of seed region 2' therein.

[0038] Channel 17' of seed region 2' and the frame structure of blanket region 3' may be linked by means of detents, located in the upper section of fuel assembly 1', as shown in Fig. 3, using a ball detent, 23, that interacts with a shell ring, 24, that is secured to the frame structure of blanket region 3'.

[0039] As indicated above and as shown in Fig. 4, the fuel elements 7' of the outermost rows and columns of the square coordinate grid of seed region 2' have a smaller width across corners than that of the remaining fuel elements 7'of seed region 2'. In order to stabilize the relative position of the fuel elements 7'fuel elements within channel 17', devices are positioned on its interior surface for limiting the lateral movement of the fuel elements 7'.

[0040] The layout of the fuel elements in the peripheral region of a seed region that conforms to the second embodiment of the invention is depicted in Fig. 5. All the fuel elements 7' make contact with each adjacent fuel element in bundle 7' at the tangent points of spiral spacer ribs 9, which are apart from one another in the axial direction at a distance equal 25% of the spiral line pitch value. The points where fuel elements 7' make contact with channel 17' of seed region 2' may be located in the regions of raised areas 25 (in the deformed areas of channel 17'), as shown in the right-hand part of Fig. 5. Spacer rods, 26, may be used as an alternative, as shown in the top part of Fig. 5, which are arranged in the axial direction and are attached to lower nozzle 6'. The solid and broken lines in Fig. 5 represent the four-lobed profiles of the fuel elements 7' fuel elements in different cross-sections in order to illustrate the locations of these contact points.

[0041] Fuel assemblies that conform to the invention at hand have fuel elements of seed region with a kernel 10, including enriched uranium or plutonium. Kernel 10 is primarily made from a uranium-zirconium (U-Zr) alloy, where the uranium fraction in the fuel compound is up to 30%, with uranium-235 isotope enrichment of up to 20%, or from a plutonium-zirconium (Pu-Zr) alloy, with a plutonium fraction of up to 30%. Displacer 12, positioned along the longitudinal axis of kernel 10, has practically square cross-sectional shape. The spiral line pitch of the spiral spacer ribs 9, amounts to 5% - 30% of the fuel element length.

[0042] The reactor core has the same geometric configuration and dimensions as in a conventional light-water reactor of the PWR type (for example, the AP-1000, the EPR, etc.), so this reactor can be re-equipped with assemblies of this type and a core can be created from the required number of fuel assemblies. An example of a light-water reactor core 27 that altogether has a round cross-section and several fuel assemblies, each of which has a square cross-section, is shown in Fig. 10.

[0043] Fuel assembly 1, which conforms to the first embodiment of the invention, is executed in the following sequence. The fuel elements 7, the tube 13, and the guide tubes 14 are positioned in the lower supporting frame structure 18 of seed region 2. Supporting frame structure 18 is secured to lower nozzle 5 of seed region 2. The upper ends of the fuel elements 7, tube 13, and the guide tubes 14 are positioned in the upper guiding grid 19. Thereafter, channel 17 is slipped over the fuel elements' bundle, and is fastened to lower nozzle 5 and guiding grid 19. Upper nozzle 4 is installed on the upper end of tube 13 and the upper ends of the guide tubes 14 then tube 13 and the guide tubes 14 are secured in the upper nozzle 4 that makes axial movement possible.

[0044] A supporting frame structure, formed by angle elements 20 and poles 21, on which spacer grids 22 are located, is secured to lower nozzle 6 of blanket region 3. The fuel elements 8 of blanket region 3 are positioned in the spacer grids 22. Thereafter, upper nozzle 4 and seed region 2, containing the fuel elements 7, which is connected to the upper nozzle by means of tube 13 and the guide tubes 14, are inserted into the opening in the spacer grids 22, whereupon the lower sections of tube 13 and the peripheral guide tubes 14, are passed through lower nozzle 6 of blanket region and are subsequently secured, using a threaded joint 15, or a collet fixture 16. Thus, seed region 2 and blanket region 3 are linked to one another.

[0045] Aggregate fuel assembly 1 is installed in the reactor core 27.

[0046] After fuel assembly 1' is removed from reactor core 27, fuel assembly 1 is dismantled in reverse order.

[0047] Fuel assembly 1', which conforms to the second embodiment of the invention, is executed in different ways, depending upon the method, used for the relative anchoring of seed region 2' and blanket region 3'.

[0048] 1. If a ball detent 23 is used, it is fastened to channel 17'. Further seed region 2' is executed in a manner similar to seed region 2 in the first embodiment of the invention. The bundle 7' fuel elements, tube 13, and the guide tubes 14 are positioned in the lower supporting frame structure 18 of seed region 2'. Supporting frame structure 18 is secured to seed region 2' lower nozzle 5'. The upper ends of the bundle 7' fuel elements, tube 13, and the guide tubes 14, are positioned in upper guiding grid 19. Thereafter, channel 17' is slipped over the fuel elements' bundle, whereupon it is secured to lower nozzle 5' and guiding grid 19. Upper nozzle 4 is installed on the upper end of tube 13 and the upper ends of the guide tubes 14, whereupon tube 13 and the guide tubes 14, are secured so as to make axial movement possible.

[0049] The peripheral guide tubes 14', are installed in the lower nozzle 6 of blanket region 3' and the spacer grids 22 are fastened to the guide tubes 14'. The grids 22 form the frame structure of blanket region 3'. The fuel elements 8 of blanket region 3' are positioned in the spacer grids 22 and in shell ring 24.

[0050] Thereafter, upper nozzle 4 and seed region 2', containing the fuel elements 7', which is connected to the upper nozzle by means of tube 13 and the peripheral guide tubes 14' are inserted into the opening in the spacer grids 22 and the guide tubes 14' are secured within upper nozzle 4, so as to make axial movement possible. Ball detent 23 ensures the relative anchoring of seed region 2' and the frame structure of blanket region 3'.

[0051] Aggregate fuel assembly 1 is installed in reactor core 27.

[0052] After fuel assembly 1' is removed from reactor core 27, it is dismantled in reverse order. 2. If a threaded joint or a collet fixture is used, fuel assembly 1' is put together and dismantled in a manner similar to that, in which the fuel assembly in the first embodiment of the invention is put together/dismantled; i.e., lower nozzle 5 of seed region 2' and lower nozzle 6 of blanket region 3' are interconnected by means of a threaded joint 15 or a collet fixture 16.

[0053] In the reactor core 27, fuel assemblies 1 and 1' function similar to the way this occurs in known reactors of the PWR type (for example, the AP-1000, the EPR, etc.).

[0054] The use of the invention at hand makes it possible to ensure that the conservation of natural uranium is achieved due to the presence of a thorium component (the blanket region) in the fuel assembly design, since a secondary nuclear fuel in the form of uranium-233 accumulates over the course of the thorium burnout process, the combustion of which makes a significant contribution to the power generation of a core that contains assemblies of this type. This results in the improvement of non-proliferation characteristics and the simplification of the problem of handling spent fuel assemblies, since the accumulation of the secondary nuclear fuel (a plutonium suitable for making nuclear weapons) that is traditional for PWR reactors (for example, the AP-1000, the EPR, etc.) is reduced to a considerable extent (by 80%), while the new secondary nuclear fuel - uranium-233 (or more precisely, the portion thereof that is left over following its combustion in a thorium blanket region "*in situ*") - is unsuitable for making nuclear weapons due to its contamination by a uranium-232 isotope and even plutonium isotopes. Herewith, it is possible to simplify the problem of handling spent fuel assemblies by means of reducing waste volumes through an increase in specified fuel life and through a decrease in the content of isotopes with long-term radiation toxicity in the discharged fuel.

[0055] Designing a fuel assembly in accordance with the invention at hand facilitates its use in reactors of the PWR type (for example, the AP-1000, the EPR, etc.) due to its mechanical, hydraulic, and neutronic compatibility with the standard fuel assembly designs.

[0056] The following ensure mechanical compatibility with the standard fuel assembly of a PWR reactor (for example, the AP-1000, the EPR, etc.):

- the presence of a load-bearing frame structure that ensures resistance to deformation during prolonged operation and when high fuel burnouts are present, together with the identical nature of the connection dimensions;
- the use of lower nozzle, upper nozzle, and load-bearing frame structure designs that are compatible with those of the similar components of standard fuel assemblies, and;
- the compatibility of the seed region design with the designs of standard controls and recharging devices.

[0057] All the hydraulic characteristics of a fuel assembly that conforms to the invention at hand are in virtual agreement with those of a standard fuel assembly due to the presence of a system of two parallel channels, formed by the seed and blanket regions that are joined by common distributing (discharge) and return upper nozzleers. Herewith, the seed and blanket regions are hydraulically interlinked within the lower inlet and upper outlet sections. This fuel assembly execution ensures that the resistance of the core of a reactor of the PWR type (for example, the AP-1000, the EPR, etc.) with fuel assembles that conform to the invention remains at the standard value level. Thus, the installation of fuel assemblies that conform to the invention at hand in a PWR reactor (for example, the AP-1000, the EPR, etc.) does not lead to a change in the coolant flow rate in the reactor's primary circuit. Here, the hydraulic resistance ratio between the assembly inlet, the core section of the blanket region, and the assembly outlet in fuel assemblies that conform to the invention and in a standard fuel assembly are close, which ensures the hydraulic compatibility of fuel assemblies that conform to the invention with standard assemblies, as well as the absence of unconventional (additional) coolant leaks between them. This makes it possible to use some of fuel assemblies that conform to the invention at hand in a reactor at the same time that standard reactor fuel assemblies are used.

[0058] The following ensure neutron-physical compatibility with a standard fuel assembly:

- the specified life until burnout is achieved through the use of specially selected fuel compounds and compounds that contain a burnable absorber;
- the standard power of a fuel assembly is achieved through the use of specially selected fuel charge contents in the seed and blanket region fuel compounds;
- the satisfaction of the requirements governing energy release profile nonuniformity is achieved through the use of specially selected fuel charge contents in the various rows of the seed region fuel elements and the fuel charge content in the blanket region;
- retaining the reactivity effects within the range, typical for standard fuel assemblies, is achieved through the use of specially selected fuel compound characteristics, and;
- the compatibility of the two-section fuel assembly design with a standard fuel channel (tube) arrangement for housing the controls ensures the possibility of power level regulation and power discharge by standard controls.

[0059] An advantage of the invention at hand is also the fact that a two-section fuel assembly, conforming to this invention, is dismountable, which makes it possible to ensure an independent modular charging of the seed region. More frequent modular charging of seed region makes it possible to create more favorable conditions (as far as neutron balance and duration of irradiation) for the thorium, placed into an assembly's blanket region.

Claims

1. A fuel assembly (1) for a light-water nuclear reactor with a square shape in the plan view and comprising:

   a seed region (2), including a bundle of seed fuel rods (7) that are arranged in the rows and columns of a square coordinate grid in a cross-section; wherein each seed fuel rod (7) comprises a kernel (10) that includes enriched uranium or plutonium;
   a blanket region (3), surrounding the aforementioned seed region (2) and including a bundle of breeding fuel rods (8), each of which comprises ceramic thorium; wherein the breeding fuel rods (8) are arranged in rows and columns of a square coordinate grid and;

   characterized in that the rows and columns of the square coordinate grid form a plurality of square-shaped rings;
   and **in that** the breeding fuel rods (8) in the fuel assembly's cross-section are positioned in the two outermost rows and columns of a square coordinate grid made up of 19 rows and 19 columns, while the seed fuel rods (7) are positioned in the rows and columns of a square coordinate grid, made up of 13 rows and 13 columns.

2. The fuel assembly of claim 1, wherein the plurality of square-shaped rings consists of two square-shaped rings.

3. The fuel assembly of claim 1 or 2, comprising guide tubes (14), positioned within the seed region (2) in such a manner, as to match the position of the guide tubes for the fuel assembly control rods of a PWR-type nuclear reactor, thereby ensuring their interchangeability.

4. The fuel assembly of claim 1 or 2, comprising 24 guide tubes (14), positioned within the seed region

(2) in such a manner, as to match the position of the 24 guide tubes of the 17×17 fuel assembly control rods of a PWR-type reactor, thereby ensuring their interchangeability.

5. The fuel assembly of any preceding claim, wherein each of the set of seed fuel rods (7) has a four-lobed profile, forming spiral spacer ribs (9).

6. The fuel assembly of any preceding claim, comprising a channel (17) that has a square cross-sectional shape and separates the seed fuel rods (7) from the breeding fuel rods (8).

7. The fuel assembly of claim 6, comprising a seed region lower nozzle (5), connected to the channel (17), wherein the fuel assembly (1) further comprises a supporting frame structure (19) that is fastened to the seed region lower nozzle (5) for the purpose of securing the seed fuel rods (7).

8. The fuel assembly of claim 6 or 7, comprising a guiding grid (19) that is secured to the upper section of the channel (17), in order to facilitate the placement of the seed fuel rods (7), so as to make possible their free axial movement.

9. The fuel assembly of any preceding claim, wherein the blanket region (3) comprises a blanket region lower nozzle (6), as well as lengthwise-arranged angle elements (20) and several lengthwise-arranged poles (21); herewith, the blanket region lower nozzle (6) is rigidly connected to the aforementioned angle elements (20) and poles (21), thereby forming a frame structure of blanket region.

10. A fuel assembly (1') for a light-water nuclear reactor with a square shape in the plan view and comprising:

a seed region (2'), including a bundle of seed fuel rods (7') that are arranged in the rows and columns of a square coordinate grid in a cross-section; wherein each seed fuel rod (7') comprises a kernel (10) that includes enriched uranium or plutonium;
a blanket region (3'), surrounding the aforementioned seed region (2') and including a bundle of breeding fuel rods (8'), each of which comprises ceramic thorium; wherein the breeding fuel rods (8') are arranged in rows and columns of a square coordinate grid;

characterized in that the rows and columns of the square coordinate grid of the breeding fuel rods (8') form three square-shaped rings;
and **in that** the seed fuel rods (7') and the breeding fuel rods (8') within the fuel assembly's cross-section are arranged in the 17 rows and 17 columns of a square coordinate grid;
wherein the seed fuel rods (7') are positioned in 11 rows and 11 columns within this grid's midsection.

11. The fuel assembly of claim 10, comprising guide tubes (14'), positioned within the seed region (2') in such a manner, as to match the position of the guide tubes for the fuel assembly control rods of a PWR-type nuclear reactor, thereby ensuring their interchangeability.

12. The fuel assembly of claim 10, comprising 24 guide tubes (14, 14'), 16 of which are positioned within the seed region (2') in such a manner, as to match the position of the 24 guide tubes of the 17×17 fuel assembly control rods of a PWR-type reactor, thereby ensuring their interchangeability.

13. The fuel assembly of any of claims 10 to 12, wherein each of the set of seed fuel rods (7') has a four-lobed profile, forming spiral spacer ribs (9).

14. The fuel assembly of any of claims 10 to 13, comprising a seed region lower nozzle (5'), connected to a square cross-sectional shaped channel (17') that separates the seed fuel rods (7') from the breeding fuel rods (8'), wherein the fuel assembly (1') further comprises a supporting frame structure (19) that is fastened to the seed region lower nozzle (5') for the purpose of securing the seed fuel rods (7').

15. The fuel assembly of claim 14, comprising a guiding grid (19) that is secured to the upper section of the channel (17'), in order to facilitate the placement of the seed fuel rods (7'), so as to make possible their free axial movement.

16. The fuel assembly of claim 10, comprising guide tubes (14, 14'), some of which are situated within the seed region (2'), while the remaining tubes (14') are situated within the blanket region (3'); herewith, all the guide tubes (14, 14') are positioned in such a manner, as to match the position of the guide tubes for the fuel assembly control rods of a PWR-type nuclear reactor, thereby ensuring their interchangeability.

17. The fuel assembly of any of claims 10 to 16 , wherein the plurality of seed fuel rods (7') includes a plurality of primary seed fuel rods that are located in the fuel assembly's cross-section and that are arranged in 9 rows and 9 columns in the midsection of a square coordinate grid, as well as a plurality of secondary seed fuel rods that are positioned in the outermost rows and columns of the midsection of a square coordinate grid; wherein each of the plurality of primary seed fuel rods has a larger width across corners than that of each secondary seed fuel rod.

18. A light-water nuclear reactor comprising a set of fuel assemblies including the fuel assembly (1, 1') according to any preceding claim.

Patentansprüche

1. Brennelement (1) für einen Leichtwasserkernreaktor mit einer quadratischen Form in der Draufsicht, das Folgendes umfasst:

Seed-Region (2), einschließlich eines Bündels an Seed-Brennstäben (7), die in Zeilen und Spalten eines quadratischen Koordinatenrasters im Querschnitt angeordnet sind, wobei jeder einzelne Seed-Brennstab (7) einen Kern (10) umfasst, der angereichertes Uran bzw. Plutonium beinhaltet;
Mantelregion (3), die die zuvor genannte Seed-Region (2) umschließt und ein Bündel an Brutstäben (8) beinhaltet, von denen jeder einzelne keramisches Thorium umfasst, wobei die Brutstäbe (8) in Zeilen und Spalten eines quadratischen Koordinatenrasters angeordnet sind und;

dadurch gekennzeichnet, dass die Zeilen und Spalten des quadratischen Koordinatenrasters eine Vielzahl an quadratförmigen Ringen bildet;
und dadurch, dass die Brutstäbe (8) im Querschnitt des Brennelements in den beiden äußersten Zeilen und Spalten eines aus 19 Zeilen und 19 Spalten bestehenden quadratischen Koordinatenrasters positioniert sind, während die Seed-Brennstäbe (7) in den Zeilen und Spalten eines aus 13 Zeilen und 13 Spalten bestehenden quadratischen Koordinatenrasters positioniert sind.

2. Brennelement nach Anspruch 1, wobei die Mehrzahl der quadratförmigen Ringe aus zwei quadratförmigen Ringen besteht.

3. Brennelement nach Anspruch 1 oder 2, das Führungsrohre (14) umfasst, die so innerhalb der Seed-Region (2) positioniert sind, dass sie mit der Position der Führungsrohre für die Steuerstäbe des Brennelements eines Druckwasserkernreaktors übereinstimmen, wodurch ihre Austauschbarkeit gewährleistet ist.

4. Brennelement nach Anspruch 1 oder 2, das 24 Führungsrohre (14) umfasst, die so innerhalb der Seed-Region (2) positioniert sind, dass sie mit der Position der 24 Führungsrohre für die 17 x 17 Steuerstäbe des Brennelements eines Druckwasserreaktors übereinstimmen, wodurch ihre Austauschbarkeit gewährleistet ist.

5. Brennelement nach einem der vorhergehenden Ansprüche, wobei jeder einzelne der Seed-Brennstäbe (7) ein Profil mit vier Nocken in der Form von spiralförmigen Abstandshalterrippen (9) aufweist.

6. Brennelement nach einem der vorhergehenden Ansprüche, das einen Kanal (17) umfasst, der einen quadratischen Querschnitt aufweist und die Seed-Brennstäbe (7) von den Brutstäben (8) trennt.

7. Brennelement nach Anspruch 6, das eine Düse (5) im unteren Bereich der Seed-Region umfasst, die mit dem Kanal (17) verbunden ist, wobei das Brennelement (1) ferner eine Stützrahmenstruktur (19) umfasst, die an der Düse (5) im unteren Bereich der Seed-Region zur Sicherung der Seed-Brennstäbe (7) befestigt ist.

8. Brennelement nach Anspruch 6 oder 7, das ein Führungsgitter (19) umfasst, das am Oberteil des Kanals (17) angebracht ist, um die Platzierung der Seed-Brennstäbe (7) zu begünstigen und ihnen eine freie Axialbewegung zu ermöglichen.

9. Brennelement nach einem der vorhergehenden Ansprüche, wobei die Mantelregion (3) im unteren Bereich der Mantelregion eine Düse (6) sowie längs angeordnete Winkelelemente (20) und mehrere längs angeordnete Stangen (21) umfasst; dadurch wird die Düse (6) der unteren Mantelregion starr mit den zuvor genannten Winkelelementen (20) und Stangen (21) verbunden und eine Rahmenstruktur der Mantelregion gebildet.

10. Brennelement (1') für einen Leichtwasserkernreaktor mit einer quadratischen Form in der Draufsicht, das Folgendes umfasst:

Seed-Region (2'), einschließlich eines Bündels an Seed-Brennstäben (7'), die in Zeilen und Spalten eines quadratischen Koordinatenrasters im Querschnitt angeordnet sind, wobei jeder einzelne Seed-Brennstab (7') einen Kern (10) umfasst, der angereichertes Uran bzw. Plutonium beinhaltet;
Mantelregion (3'), die die zuvor genannte Seed-Region (2') umschließt und ein Bündel an Brutstäben (8') beinhaltet, von denen jeder einzelne keramisches Thorium umfasst, wobei die Brutstäbe (8') in Zeilen und Spalten eines quadratischen Koordinatenrasters angeordnet sind;
dadurch gekennzeichnet, dass die Zeilen und Spalten des quadratischen Koordinatenrasters der Brutstäbe (8') drei quadratförmige Ringe bilden;

und dadurch, dass die Seed-Brennstäbe (7') und die Brutstäbe (8') innerhalb des Querschnitts des Brennelements in 17 Zeilen und 17 Spalten eines quadratischen Koordinatenrasters angeordnet sind; wobei die Seed-Brennstäbe (7') innerhalb des mittleren Bereichs dieses Rasters in 11 Zeilen und 11 Spalten angeordnet sind,

11. Brennelement nach Anspruch 10, das Führungsrohre (14') umfasst, die so innerhalb der Seed-Region (2') positioniert sind, dass sie mit der Position der Führungsrohre für die Steuerstäbe des Brennelements eines Druckwasserkernreaktors übereinstimmen, wodurch ihre Austauschbarkeit gewährleistet ist.

12. Brennelement nach Anspruch 10, das 24 Führungsrohre (14, 14') umfasst, von denen 16 so innerhalb der Seed-Region (2') positioniert sind, dass sie mit der Position der 24 Führungsrohre für die 17 x 17 Steuerstäbe des Brennelements eines Druckwasserreaktors übereinstimmen, wodurch ihre Austauschbarkeit gewährleistet ist.

13. Brennelement nach einem der Ansprüche 10 bis 12, wobei jeder einzelne der Seed-Brennstäbe (7') ein Profil mit vier Nocken in der Form von spiralförmigen Abstandshalterrippen (9') aufweist.

14. Brennelement nach einem der Ansprüche 10 bis 13, das eine Düse (5') im unteren Bereich der Seed-Region umfasst, die mit einem vom Querschnitt quadratförmigen Kanal (17') verbunden ist, der die Seed-Brennstäbe (7') von den Brutstäben (8') trennt, wobei das Brennelement (1') ferner eine Stützrahmenstruktur (19) umfasst, die an der Düse (5') im unteren Bereich der Seed-Region zur Sicherung der Seed-Brennstäbe (7') befestigt ist.

15. Brennelement nach Anspruch 14, das ein Führungsgitter (19) umfasst, das am Oberteil des Kanals (17') angebracht ist, um die Platzierung der Seed-Brennstäbe (7') zu begünstigen und ihnen eine freie Axialbewegung zu ermöglichen.

16. Brennelement nach Anspruch 10, das Führungsrohre (14, 14') umfasst, von denen einige innerhalb der Seed-Region (2'), während die restlichen Rohre (14') innerhalb der Mantelregion (3') liegen; dadurch werden all die Führungsrohre (14, 14') so positioniert, dass sie mit der Position der Führungsrohre für die Steuerstäbe des Brennelements eines Druckwasserkernreaktors übereinstimmen, wodurch ihre Austauschbarkeit gewährleistet ist.

17. Brennelement nach einem der Ansprüche 10 bis 16, wobei die Vielzahl an Seed-Brennstäben (7') eine Vielzahl an primären Seed-Brennstäben, die sich im Querschnitt des Brennelements befinden und im mittleren Bereich eines quadratischen Koordinatenrasters in 9 Zeilen und 9 Spalten angeordnet sind, sowie eine Vielzahl an sekundären Seed-Brennstäben, die in den äußersten Zeilen und Spalten des mittleren Bereichs eines quadratischen Koordinatenrasters positioniert sind, beinhaltet; wobei jeder einzelne der Vielzahl an primären Seed-Brennstäben eine größere Breite an den Ecken aufweist als bei jedem einzelnen sekundären Seed-Brennstab.

18. Leichtwasserkernreaktor, der einen Satz an Brennelementen, einschließlich des Brennelements (1, 1') entsprechend eines der vorhergehenden Ansprüche, umfasst.

Revendications

1. Ensemble combustible (1) d'un réacteur nucléaire à eau légère de forme carrée dans la vue en plan et comprenant :

une région de semences (2), y compris un faisceau de barres de combustible de semences (7) disposées dans les rangées et les colonnes d'une grille de coordonnées carrées dans une section transversale ; où chaque barre de combustible de semences (7) comprend un noyau (10) qui comprend de l'uranium enrichi ou du plutonium enrichi;
une région de couverture (3), entourant la région de semences mentionnée plus haut (2) et notamment un faisceau de barres de combustible de reproduction (8), dont chacune comprend du thorium céramique; où les barres de combustible de reproduction (8) sont disposées en rangées et colonnes d'une grille de coordonnées carrés et;

caractérisé en ce que les rangées et colonnes d'une grille de coordonnées carrés forment une pluralité d'anneaux carrés;
et ce que les barres de combustible de reproduction (8) dans la section transversale de l'ensemble combustible sont positionnées dans les deux rangées et colonnes externes d'une grille de coordonnées carrée constitué de 19 rangées et 19 colonnes, tandis que les barres de combustible de semences (7) sont positionnées dans les rangées et colonnes externes d'une grille de coordonnées carrée, constituée de 13 rangées et 13 colonnes.

2. Ensemble combustible selon la revendication 1, où la pluralité des anneaux carrés est constituée de deux anneaux carrés.

3. Ensemble combustible selon les revendications 1 ou 2, comprenant des tubes de guidage (14), positionné à l'intérieur de la région de semences (2) d'une manière à correspondre à la position des tubes de guidage pour les barres de commande de l'ensemble combustible d'un réacteur nucléaire de type PWR, assurant ainsi leur interchangeabilité.

4. Ensemble combustible selon les revendications 1 ou 2, comprenant 24 tubes de guidage (14), positionnés à l'intérieur de la région de semences (2) de manière à correspondre à la position des 24 tubes de guidage des 17 x 17 barres de commande de l'ensemble combustible d'un réacteur nucléaire de type PWR, assurant ainsi leur interchangeabilité.

5. Ensemble combustible selon une quelconque revendication précédente, où chacune de l'ensemble des barres de combustible de semences (7) présente un profil à quatre lobes, formant des nervures d'écartement spiralées (9).

6. Ensemble combustible selon l'une quelconque revendication précédente, comprenant un canal (17) de forme transversale carrée et séparant les barres de combustible des semences (7) provenant des barres de combustible de reproduction (8).

7. Ensemble combustible selon la revendication 6, comprenant une buse inférieure de région de semences (5), connectée au canal (17), où l'ensemble combustible (1) comprend en outre une structure de châssis de support (19) qui est fixée à la buse inférieure de région de semences (5) pour fixer les barres de combustible de semences (7).

8. Ensemble combustible selon les revendications 6 ou 7, comprenant une grille de guidage (19) qui est fixée à la partie supérieure du canal (7), pour faciliter le placement des barres de combustible de semences (7) et ainsi rendre possible leur mouvement axial sans entraves.

9. Ensemble combustible selon l'une quelconque revendication précédente, où la région de couverture (3) comprend une buse inférieure de région de couverture (6), de même que des éléments angulaires disposés longitudinalement (20) et plusieurs pôles disposés longitudinalement (21); en cela, la buse inférieure de région de couverture (6) est rigidement connectée aux éléments angulaires (20) et aux pôles (21) mentionnés plus haut, formant ainsi une structure de châssis de la région de couverture.

10. Ensemble combustible (1') pour réacteur nucléaire à eau légère de forme carrée dans la vue en plan et comprenant :

une région de semences (2'), y compris un faisceau de barres de combustible de semences (7') disposées dans les rangées et les colonnes d'une grille de coordonnées carrées dans une section transversale ; où chaque barre de combustible de semences (7') comprend un noyau (10) qui comprend de l'uranium enrichi ou du plutonium enrichi;

une région de couverture (3'), entourant la région de semences mentionnée plus haut (2') et incluant un faisceau de barres de combustible de reproduction (8'), dont chacun comprend du thorium céramique; où les barres de combustible de reproduction (8') sont disposées en rangées et colonnes grille de coordonnées carrés;

caractérisé en ce que les rangées et colonnes d'une grille de coordonnées carrés des barres de combustible de reproduction (8') forment des anneaux carrés;

et **en ce que** les barres de combustible de semences (7') et les barres de combustible de reproduction (8') dans la section transversale de l'ensemble combustible sont disposées dans les 17 rangées et 17 colonnes d'une grille de coordonnées carrés;

où les barres de combustible de semences (7') sont positionnées dans 11 rangées et 11 colonnes dans la partie médiane de cette grille.

11. Ensemble combustible selon la revendication 10, comprenant des tubes de guidage (14'), positionnés à l'intérieur de la région de semences (2') de manière à correspondre à la position des tubes de guidage pour les barres de commande de l'ensemble combustible d'un réacteur nucléaire de type PWR, assurant ainsi leur interchangeabilité.

12. Ensemble combustible selon la revendication 10, comprenant 24 tubes de guidage (14, 14'), dont 16 sont positionnés à l'intérieur de la région de semences (2') de manière à correspondre à la position des 24 tubes de guidage des 17 x 17 barres de commande de l'ensemble combustible d'un réacteur nucléaire de type PWR, assurant ainsi leur interchangeabilité.

13. Ensemble combustible selon l'une quelconque des revendications 10 à 12, où chacune de l'ensemble des barres de combustible de semences (7') présente un profil à quatre lobes, formant des nervures d'écartement spiralées (9).

14. Ensemble combustible selon l'une quelconque des revendications 10 à 13, comprenant une buse inférieure de région de couverture (5'), connecté à un canal de section transversale (17') qui sépare les barres de combustible de semences (7') des barres de combustible de reproduction (8'), où l'ensemble combustible (1') comprend en outre une structure de châssis de support (19) qui est fixée à la buse inférieure de région de semences (5') pour fixer les barres de combustible de semences (7').

15. Ensemble combustible selon la revendication 14, comprenant une grille de guidage (19) qui est fixée à la partie supérieure du canal (17’), pour faciliter le placement des barres de combustible de semences (7’) et ainsi rendre possible leur mouvement axial sans entraves.

16. Ensemble combustible selon la revendication 10, comprenant des tubes de guidage (14, 14’), dont plusieurs sont positionnés à l’intérieur de la région de semences (2’), tandis que les tubes restants (14’) sont situés dans la région de couverture (3’); en cela, tous les tubes de guidage (14, 14’) sont disposés de manière à correspondre à la position des tubes de guidage pour les barres de commande de l’ensemble combustible d’un réacteur nucléaire de type PWR, assurant ainsi leur interchangeabilité.

17. Ensemble combustible selon l’une quelconque des revendications 10 à 16, où la pluralité des barres de combustible de semences (7’) inclut une pluralité de barres de combustible de semences primaires qui sont situées dans la section transversale de l’ensemble combustible et qui sont disposées en 9 rangées et 9 colonnes dans la section médiane d’une grille de coordonnées carrés, de même qu’une pluralité de barres de combustible de semences secondaires qui sont positionnées dans les rangées et colonnes externes de la section médiane d’une grille de coordonnées carrés; où chacune de la pluralité des barres de combustible de semences primaires a un plus grand diamètre d’un coin à l’autre que celui de chaque barre de combustible de semences secondaire.

18. Réacteur nucléaire à eau légère comprenant un jeu d’ensembles combustibles, y compris l’ensemble combustible (1,1’) selon une quelconque revendication précédente.

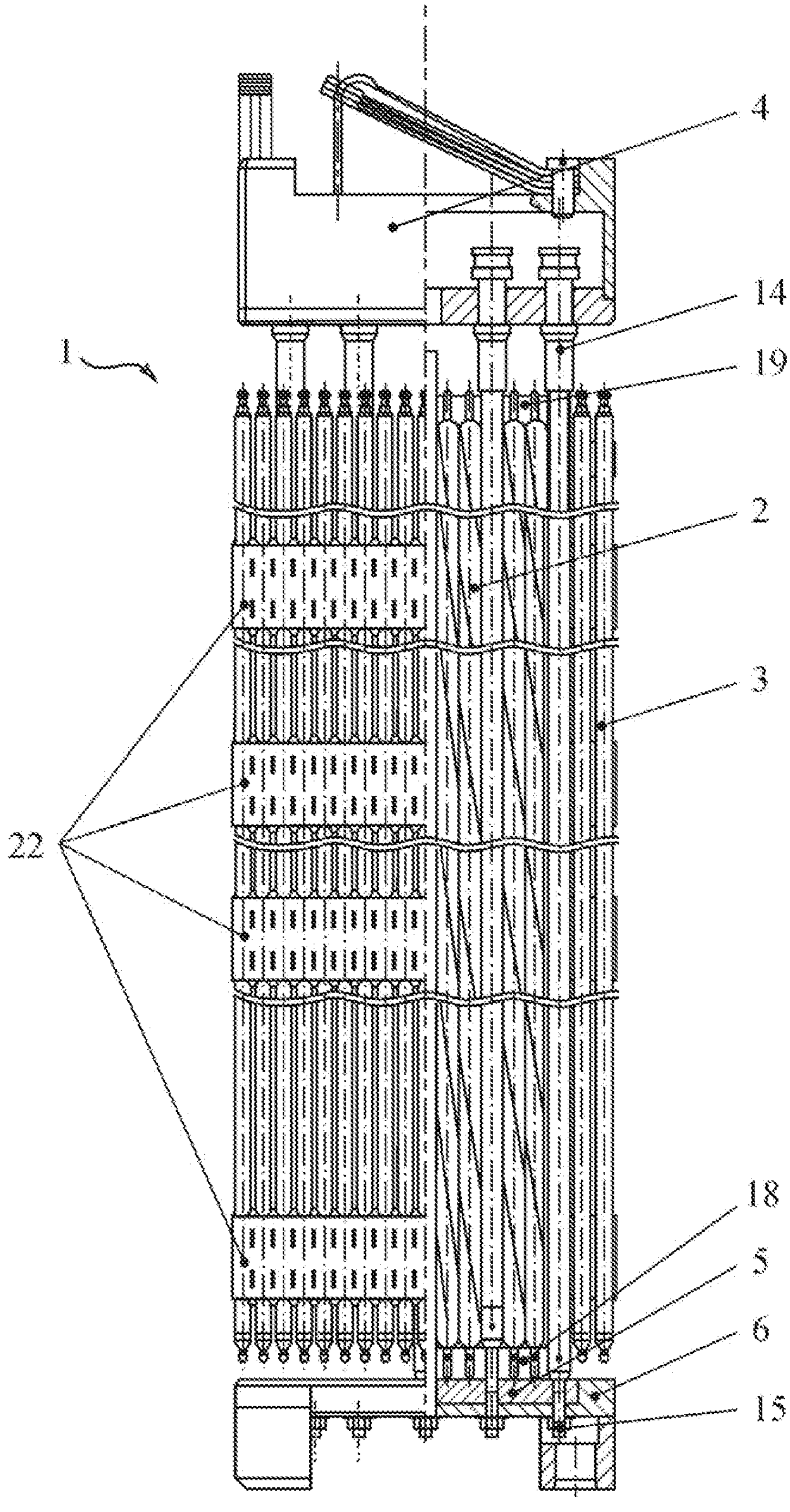


FIG. 1

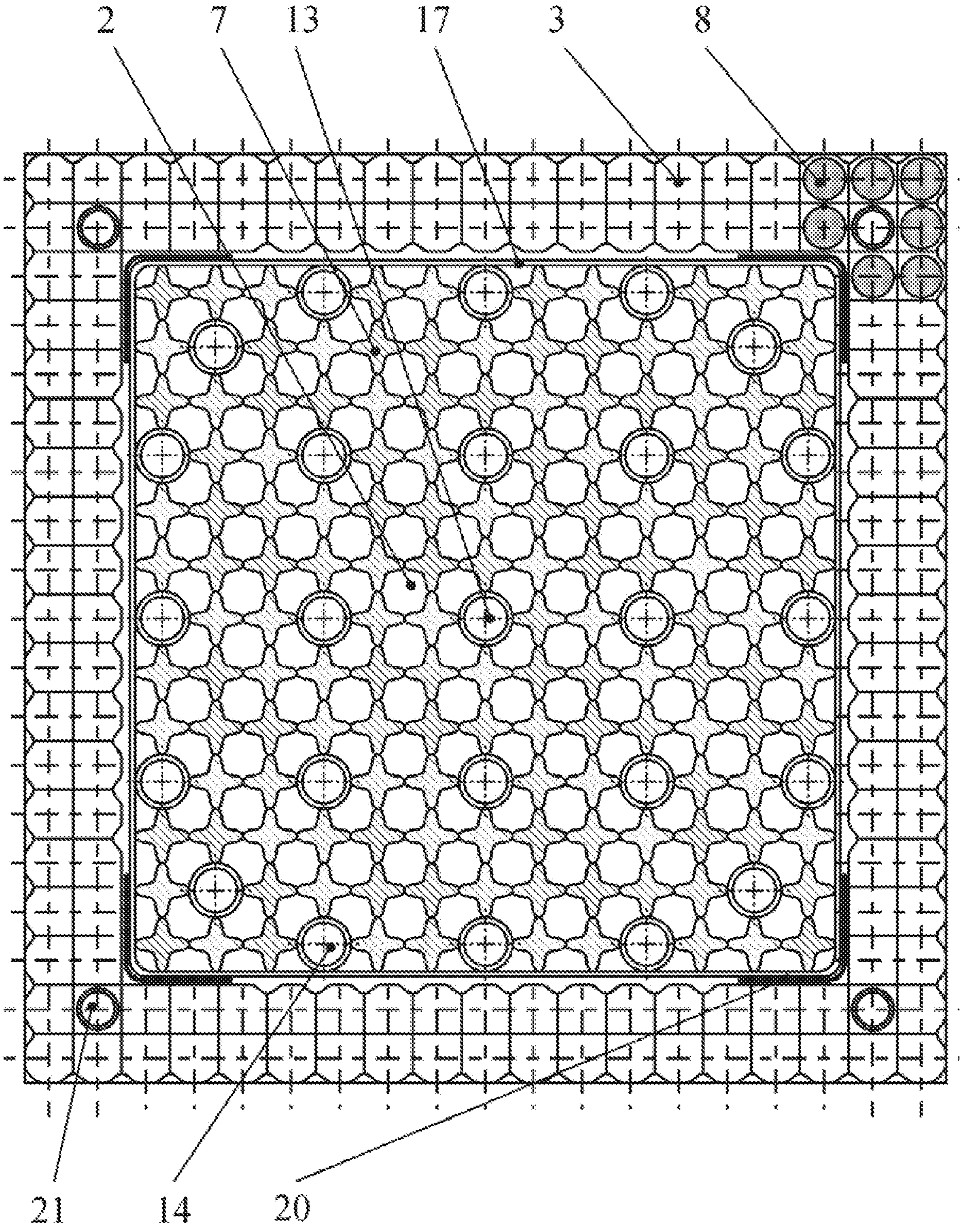


FIG. 2

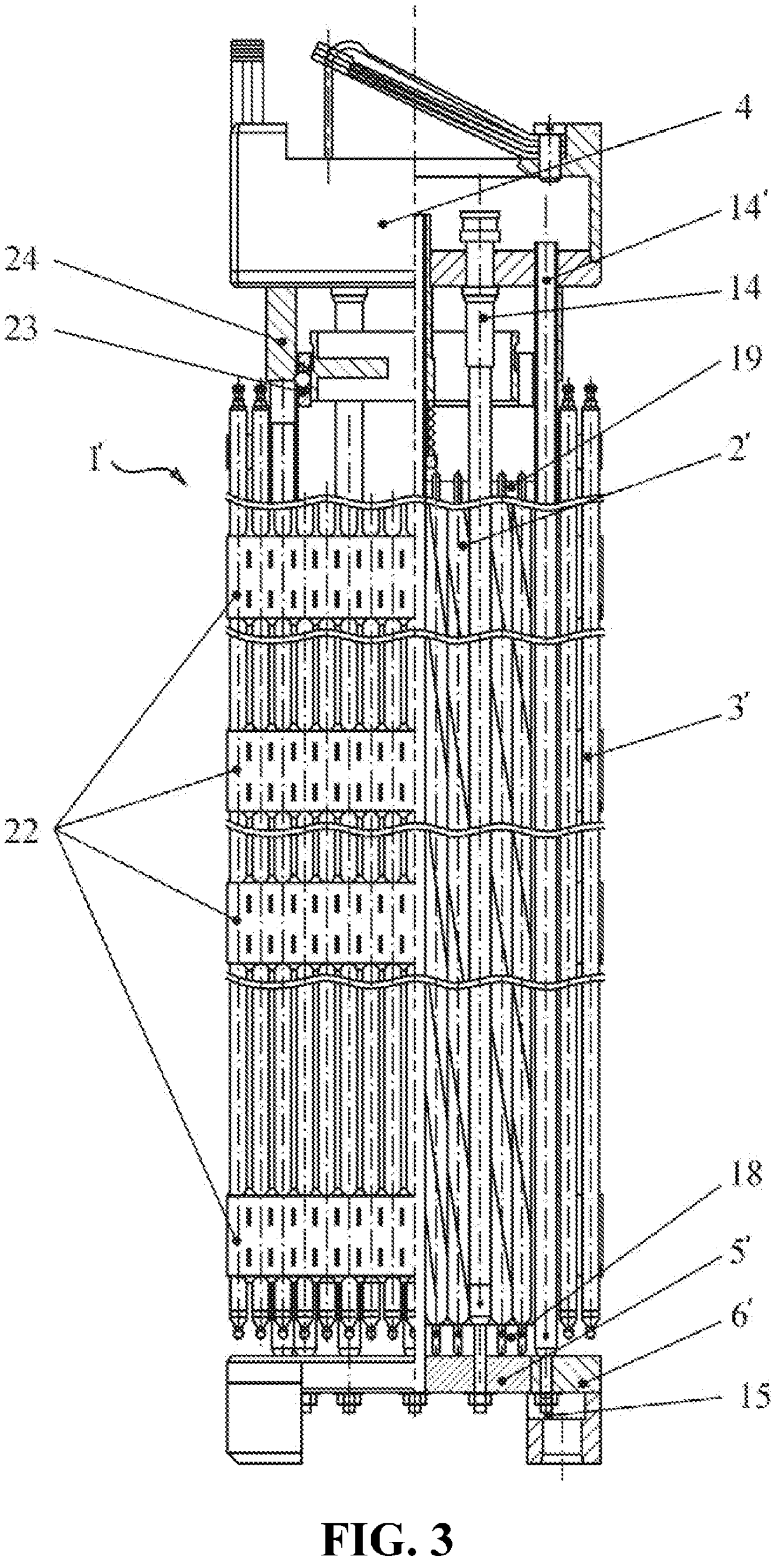


FIG. 3

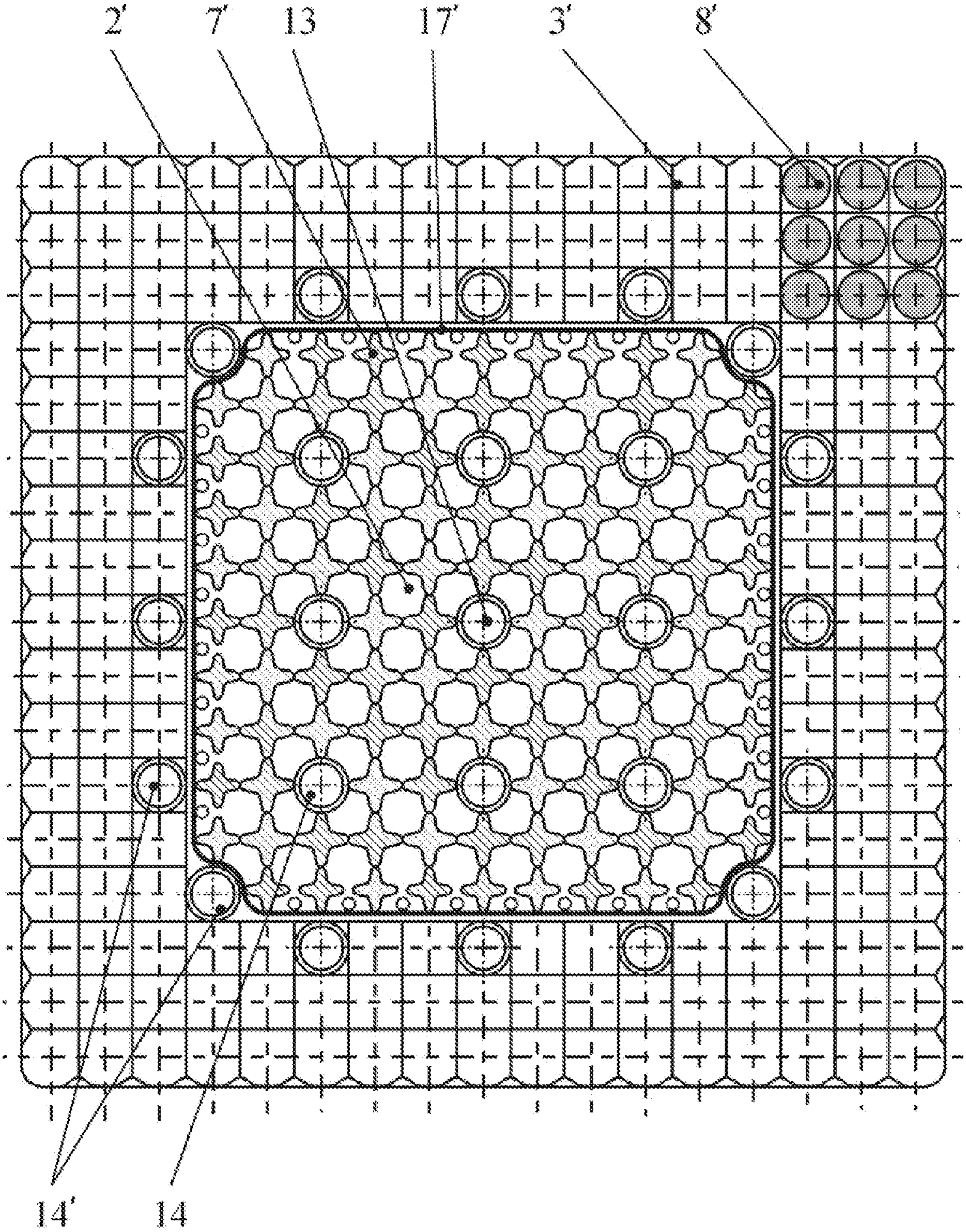


FIG. 4

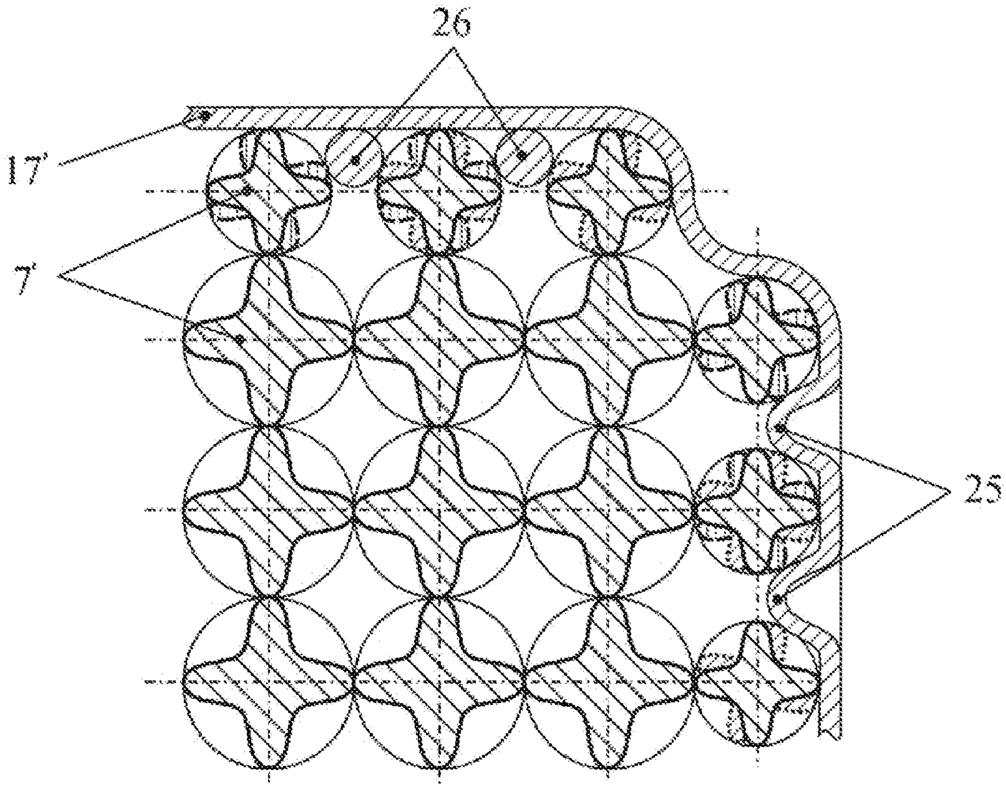
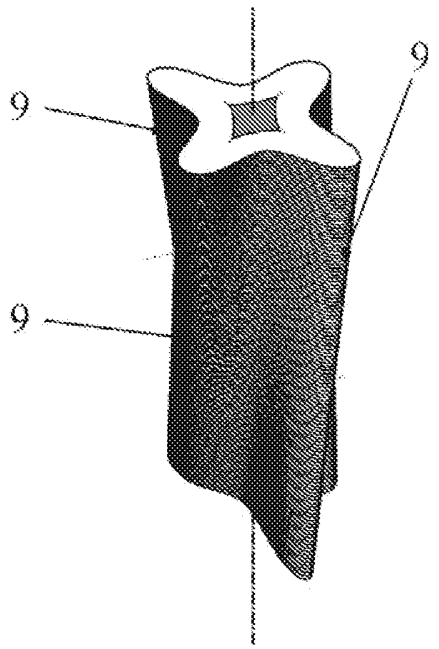


FIG. 5



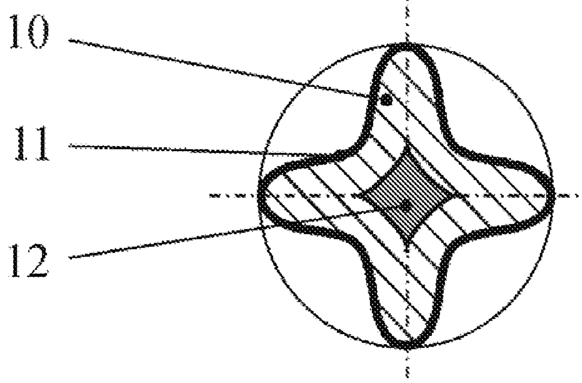


FIG. 6

FIG. 7

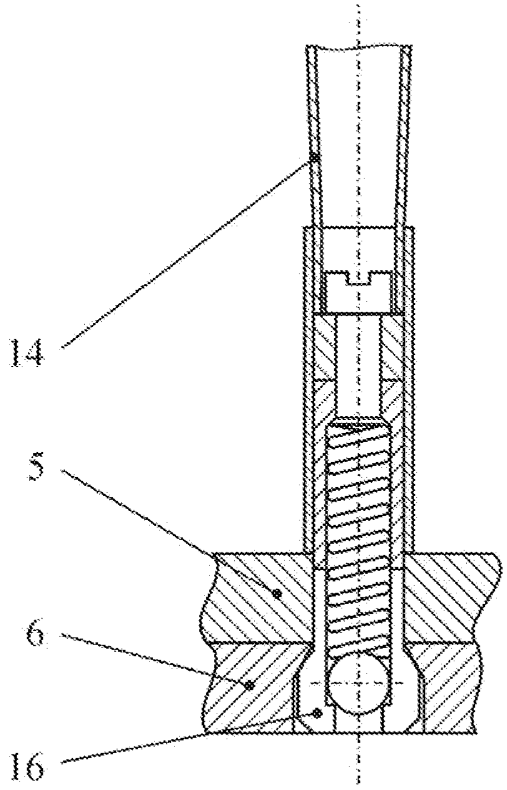


FIG. 8

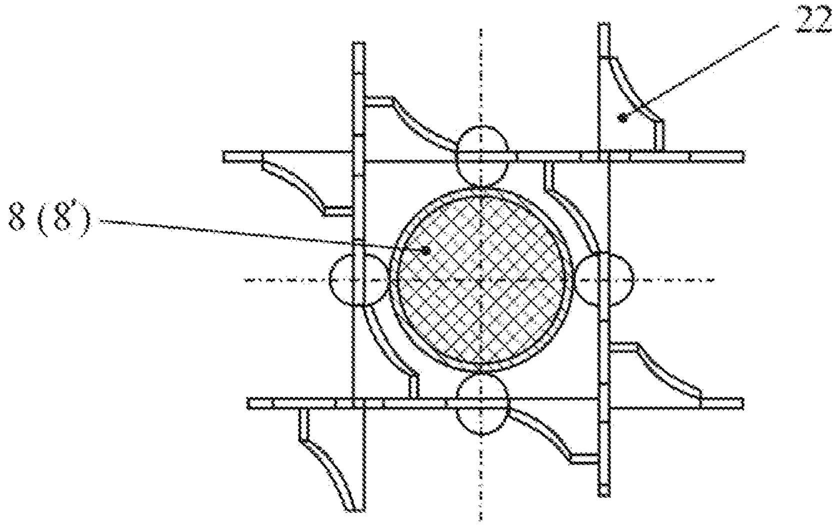


FIG. 9

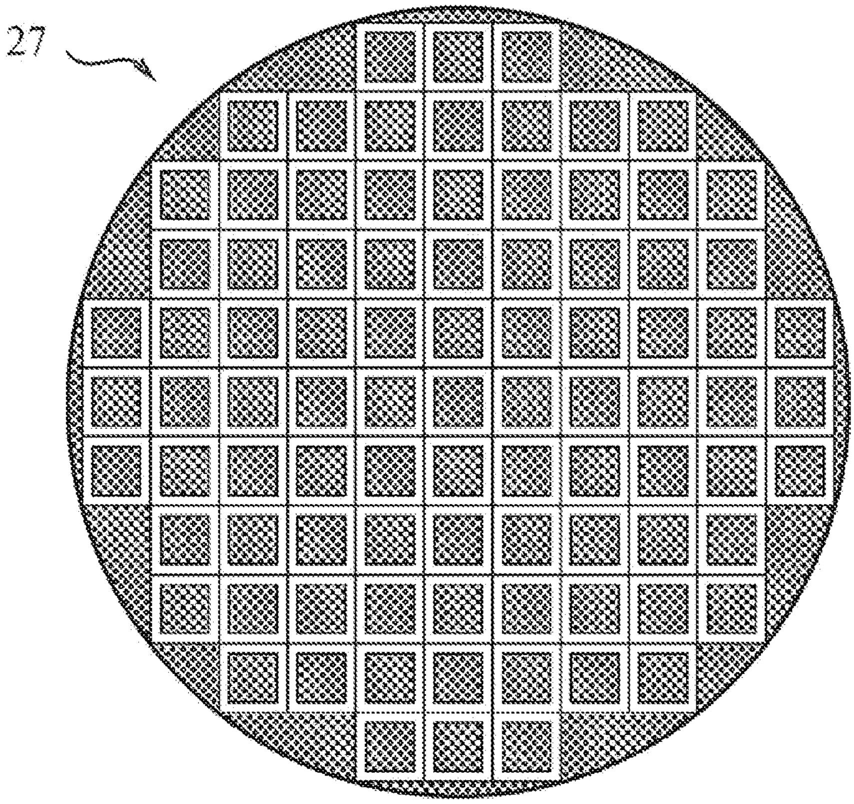


FIG. 10

REFERENCES CITED IN THE DESCRIPTION

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FŰTŐELEM-EGYSÉG EGY KÖNNYŰVIZES NUKLEÁRIS REAKTORHOZ ÉS KÖNNYŰVIZES NUKLEÁRIS REAKTOR

Szabadalmi igénypontok

1. Fűtőelem-egység (1) egy könnyűvizes nukleáris reaktorhoz, amely a felülnézetben egy négyzet alakkal rendelkezik és magában foglalja a következőket:

egy mag-részt (angolul: „seed-region") (2), amely magában foglal egy köteget, amely mag-fűtőelem-pálcákból („angolul: seed fuel rods") (7) áll, amelyek egy négyzetes koordináta-rácsnak a soraiban és oszlopaiban vannak elrendezve egy keresztmetszetben; ahol minden egyes mag-fűtőelem-pálca (7) magában foglal egy magot (angolul: „kernel") (10), amely tartalmaz dúsított urániumot illetve plutóniumot;

egy köpeny-részt (angolul: „blanket region") (3), amely körülzárja a fennebb megnevezett mag-részt (2) és magában foglal egy köteget, amely tenyésztő-fűtőelem-pálcákból („angolul: breeding fuel rods") (8) áll, amelyek közül mindegyik tartalmaz keramikus tóriumot (angolul: „ceramic thorium"); ahol a tenyésztő-fűtőelem-pálcák (8) egy négyzetes koordináta-rácsnak a soraiban és oszlopaiban vannak elrendezve és;

azzal jellemezve, hogy a négyzetes koordináta-rácsnak a sorai és oszlopai több négyzet-alakú gyűrűt képeznek;

és **azzal, hogy** a tenyésztő-fűtőelem-pálcák (8) a fűtőelem-egység keresztmetszetében egy 19 sorból és 19 oszlopból álló négyzetes koordináta-rácsnak a két legkülsőbb soraiban és oszlopaiban vannak elhelyezve, amíg a mag-fűtőelem-pálcák (7) egy 13 sorból és 13 oszlopból álló négyzetes koordináta-rácsnak a soraiban és oszlopaiban vannak elhelyezve.

2. Fűtőelem-egység az 1. igénypont szerint, ahol a több négyzet-alakú gyűrű két négyzet-alakú gyűrűből áll.

3. Fűtőelem-egység az 1. vagy 2. igénypont szerint, amely magában foglal vezetőcsöveket (14), amelyek a mag-részen (2) belül vannak elhelyezve oly módon, hogy illeszkedjenek a vezetőcsöveknek a pozíciójához, amelyek egy nyomottvizes-típusú (PWR-típusú) nukleáris reaktor fűtőelem-egység szabályozó rúdjai számára szolgálnak, ami által biztosítva van azok kicserélhetősége.

4. Fűtőelem-egység az 1. vagy 2. igénypont szerint, amely magában foglal 24 vezetőcsövet (14), amelyek a mag-részen (2) belül vannak elhelyezve oly módon, hogy illeszkedjenek egy nyomottvizes-típusú (PWR-típusú) reaktor 17 × 17 fűtőelem-egység szabályozó rúdjának a 24 vezetőcsövének a pozíciójához, ami által biztosítva van azok kicserélhetősége.

5. Fűtőelem-egység az előző igénypontok bármelyike szerint, ahol mindegyik a mag-fűtőelem-pálcákból (7) álló készlet elemei közül egy négykaréjos profillal rendelkezik, amely kialakít spirális távtartó bordákat (9).

6. Fűtőelem-egység az előző igénypontok bármelyike szerint, amely magában foglal egy csatornát (17), amely egy négyzet alakú keresztmetszettel rendelkezik és elválasztja a mag-fűtőelem-pálcákat (7) a tenyésztő-fűtőelem-pálcáktól (8).

7. Fűtőelem-egység a 6. igénypont szerint, amely magában foglal egy mag-rész alsó fúvókát (5), amely össze van kapcsolva a csatornával (17), ahol a fűtőelem-egység (1) továbbá magában foglal egy tartó-keretszerkezetet (19), amely rögzítve van a mag-rész alsó fúvókára (5) a mag-fűtőelem-pálcák (7) rögzítése céljából.

8. Fűtőelem-egység a 6. vagy 7. igénypont szerint, amely magában foglal egy vezető rácsozatot (19), amely rögzítve van a csatornának (17) a felső részére azon célból, hogy legyen elősegítve a mag-fűtőelem-pálcáknak (7) az elhelyezése úgy, hogy legyen lehetővé téve azok szabad axiális mozgása.

9. Fűtőelem-egység az előző igénypontok bármelyike szerint, ahol a köpeny-rész (3) magában foglal egy köpeny-rész alsó fúvókát (6), valamint hosszirányban-elrendezett sarokelemeket (20) és több hosszirányban-elrendezett rudat (21); ezúton a köpeny-rész alsó fúvóka (6) mereven össze van kapcsolva a fennebb megnevezett sarokelemekkel (20) és rudakkal (21), ami által a köpeny-rész egy keretszerkezete van kialakítva.

10. Fűtőelem-egység (1') egy könnyűvizes nukleáris reaktorhoz, amely a felülnézetben egy négyzet alakkal rendelkezik és magában foglalja a következőket:

egy mag-részt (angolul: „seed-region") (2'), amely magában foglal egy köteget, amely mag-fűtőelem-pálcákból („angolul: seed fuel rods") (7') áll, amelyek egy négyzetes koordináta-rácsnak a soraiban és oszlopaiban vannak elrendezve egy keresztmetszetben; ahol minden egyes mag-fűtőelem-pálca (7') magában foglal egy magot (angolul: „kernel") (10), amely tartalmaz dúsított urániumot illetve plutóniumot;

egy köpeny-részt (angolul: „blanket region") (3'), amely körülzárja a fennebb megnevezett mag-részt (2') és magában foglal egy köteget, amely tenyésztő-fűtőelem-pálcákból („angolul: breeding fuel rods") (8') áll, amelyek közül mindegyik tartalmaz keramikus tóriumot (angolul : „ceramic thorium"); ahol a tenyésztő-fűtőelem-pálcák (8') egy négyzetes koordináta-rácsnak a soraiban és oszlopaiban vannak elrendezve;

azzal jellemezve, hogy a tenyésztő-fűtőelem-pálcák (8') négyzetes koordináta-rácsának a sorai és oszlopai három négyzet-alakú gyűrűt képeznek;

és **azzal, hogy** a mag-fűtőelem-pálcák (7') és a tenyésztő-fűtőelem-pálcák (8') a fűtőelem-egység keresztmetszetén belül egy négyzetes koordináta-rácsnak a 17 sorában és 17 oszlopában vannak elrendezve;

ahol a mag-fűtőelem-pálcák (7') 11 sorban és 11 oszlopban vannak elrendezve ennek a rácsnak a középső részén belül.

11. Fűtőelem-egység a 10. igénypont szerint, amely magában foglal vezetőcsöveket (14'), amelyek a mag-részen (2') belül vannak elhelyezve oly módon, hogy illeszkedjenek a vezetőcsöveknek a pozíciójához, amelyek egy nyomottvizes-típusú (PWR-típusú) nukleáris reaktor fűtőelem-egység szabályozó rúdjai számára szolgálnak, ami által biztosítva van azok kicserélhetősége.

12. Fűtőelem-egység a 10. igénypont szerint, amely magában foglal 24 vezetőcsövet (14, 14'), amelyek közül 16 a mag-részen (2') belül van elhelyezve oly módon, hogy illeszkedjenek egy nyomottvizes-típusú (PWR-típusú) reaktor 17 × 17 fűtőelem-egység szabályozó rúdjának a 24 vezetőcsövének a pozíciójához, ami által biztosítva van azok kicserélhetősége.

13. Fűtőelem-egység a 10.-től 12.-ig igénypontok bármelyike szerint, ahol mindegyik a mag-fűtőelem-pálcákból (7') álló készlet elemei közül egy négykaréjos profillal rendelkezik, amely kialakít spirális távtartó bordákat (9).

14. Fűtőelem-egység a 10.-től 13.-ig igénypontok bármelyike szerint, amely magában foglal egy mag-rész alsó fúvókát (5'), amely össze van kapcsolva egy négyzet alakú keresztmetszetű csatornával (17'), amely elválasztja a mag-fűtőelem-pálcákat (7') a tenyésztő-fűtőelem-pálcáktól (8'), ahol a fűtőelem-egység (1') továbbá magában foglal egy tartó-keretszerkezetet (19), amely rögzítve van a mag-rész alsó fúvókára (5') a mag-fűtőelem-pálcák (7') rögzítése céljából.

15. Fűtőelem-egység a 14. igénypont szerint, amely magában foglal egy vezető rácsozatot (19), amely rögzítve van a csatornának (17') a felső részére azon célból, hogy legyen elősegítve a mag-fűtőelem-pálcáknak (7') az elhelyezése úgy, hogy legyen lehetővé téve azok szabad axiális mozgása.

16. Fűtőelem-egység a 10. igénypont szerint, amely magában foglal vezetőcsöveket (14, 14'), amelyek közül néhány a mag-részen (2') belül helyezkedik el, amíg a megmaradó csövek (14') a köpeny-részen (3') belül helyezkednek el; ezúton az összes vezetőcső (14, 14') oly módon van elhelyezve, hogy azok illeszkedjenek a vezetőcsöveknek a pozíciójához, amelyek egy nyomottvizes-típusú (PWR-típusú) nukleáris reaktor fűtőelem-egység szabályozó rúdjai számára szolgálnak, ami által biztosítva van azok kicserélhetősége.

17. Fűtőelem-egység a 10.-től 16.-ig igénypontok bármelyike szerint, ahol a több mag-fűtőelem-pálca (7') magában foglal több primer mag-fűtőelem-pálcát, amelyek a fűtőelem-egység keresztmetszetében találhatók és amelyek 9 sorban és 9 oszlopban vannak elrendezve egy négyzetes koordináta-rácsnak a középső részén, valamint több szekunder mag-fűtőelem-pálcát, amelyek egy négyzetes koordináta-rács középső részének a legkülsőbb soraiban és oszlopaiban vannak elhelyezve; ahol mindegyik a több primer mag-fűtőelem-pálca közül egy nagyobb szélességgel rendelkezik a sarkokon át, mint a szélesség, amellyel minden egyes szekunder mag-fűtőelem-pálca rendelkezik.

18. Könnyűvizes nukleáris reaktor, amely magában foglal egy fűtőelem-egységekből álló készletet, beleértve a fűtőelem-egységet (1, 1') az előző igénypontok bármelyike szerint.